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A Preliminary Information Theory of Difference

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ABSTRACT

We propose a difference theory of information. The difference theory of information defines information as adaptation, as any difference that makes a difference (Bateson 1973). The theory posits that information workers such as symbolic analysts, end users and systems analysts perceive differences and conceive information. This theory of information is applied to several IS scenarios to demonstrate its utility. One primary use from this theory is to enforce a difference between data and information.

Keywords

Information, Theory, Data

INTRODUCTION

We live in an age of information and operate an information based economy, populated largely by information workers, whom Reich (2000) calls "symbolic analysts." These analysts must function in an increasingly uncertain business environment where technology is enabling ever more symbols to be created, stored and transmitted. These analysts, these problem identifiers, problem-solvers and problem-brokers, cope with this uncertain environment via information—that is to say, they cope by becoming informed. Thus, at work and otherwise, we say that to cope is to be informed.

Unfortunately, our understanding of the process of becoming informed is limited by misuse of the term information. Information is a semantic chameleon (Thom 1975) whose definition is often taken for granted (Benyon-Davies, 2009). It is frequently used as an unspecified, reflexive, all-purpose but indiscriminant solution to an unbounded variety of problems (McKinney and Yoos, 2010). Here we propose a theory of information based on Gregory Bateson's (1973) definition of information as any difference that makes a difference.

The rest of the paper is organized as follows. We highlight common and scientific use of information with particular emphasis on theories of information within the adaptation view. The difference theory is then presented, and illuminated with examples from IS practice.

HISTORICAL AND COMMON USE PERSPECTIVES

The concept of information has been a central term in human understanding for thousands of years. There are several excellent reviews of the construct of information (see Ayers, 1994; Capurro and Hjorland, 2003; Clancey, 1997). In medieval times information implied an active, constructive activity as something which gives a certain form or character to matter or to the mind (Campbell, 1982). This fundamental role continues into the industrial age, when the demands to create communication networks rewarded theories that could objectively measure communication. The older interpretive, constructive, perspective of information was overtaken by the need for an information perspective that would be more suitable for measurability and productivity. Shannon's famous mathematical theory defined information as the measurable reduction in uncertainty (Shannon and Weaver, 1949). In this view, information is novelty: a less probable event is more informative as it reduces more uncertainty than a more probable event (Bar-Hillel and Carnap, 1953, Dretske 1981). In this context information is a communication phenomenon—the selection and transmission of entropy reducing messages (Capurro and Hjorland, 2003). This objective, reduction in uncertainty definition of information became particularly popular in mathematics, science and philosophy.

Today, the term information plays an increasingly fundamental role in a wide variety of scientific domains including physics, astronomy, biology, psychology, medicine, political science, physiology, economics, behavioral science, philosophy, and engineering (Burgin, 2010; van Rijsbergen and Laimas, 1996). It is hard to imagine another concept that is fundamental to as many domains. In fact several prominent physicists have even suggested that the physical world is comprised of information with energy and matter as incidentals. In this view, information is the language of science, that all "its" come from "bits" (von Bayer, 2004; Weizsacker, 1985).

Due to its prominence in a broad variety of scientific domains, a number of attempts have been made to synthesize a common or unified theory of information (Floridi, 2006; Hofkirchner, 1999, 2010; Kornwachs and Jacoby, 1996; Machlup and Mansfield, 1983). By their own admission, most attempts at unification have failed to achieve a satisfactory outcome (Borgmann, 1999; Burgin, 2010; van Rijsbergen and Laimas 1996).

IS Perspective

As in business in general, IS rarely addresses information and it has no accepted definition (Lee, 2010; McKinney and Yoos, 2010). Over the past 20 years only a few definitions have been offered, and the assumptions underlying these definitions have not been well vetted. A sample of these definitions defines information as data that has been organized and meaningful (Glazer, 1991), the assembly of data in comprehensive form (Rouse, 2002), patterns of organization of matter and energy (Bates, 2005), and data that have been processed (Benyon-Davies, 2009). IS textbooks also define the term in different ways. As a result, information has become reified—it is a ubiquitous term in IS without a clear definition.

Despite this lack of consensus, it is difficult to imagine a more vital term for IS. Lee sees information as more important than data (2010), Glazer suggests information is more important than the artifact (1991), and Benyon-Davies (2009) calls information foundational. Textbook authors also indicate the central role of information in IS. Another indication of the importance of the concept to the IS community is that information forms most of the important compound concepts in IS—information technology, information systems, information processing, information superhighway, information sharing, information acquisition, and IS. Finally, not only is the term important, it is growing. With storage costs plummeting, and network capacities expanding, the amount and availability of potential information is expanding relentlessly.

It is time for IS to work toward a common definition of information, a definition appropriate for the issues fundamental to IS and business. Not only does a common definition enhance the legitimacy of IS as a scientific domain (Mingers, 1995; Benbasat and Zmud, 2003), but a common definition can enable progress on issues unique to IS.

To initiate the process of presenting a widely acceptable definition of information, McKinney and Yoos (2010) classified definitions around three or four primary views. Most of these definitions for information can be classified as token, syntax, representation, and adaptation. These views vary by ontology, epistemology, and other fundamental assumptions.

As a token, information is synonymous with data and both are manipulated by processes. The token-based view is widespread in information systems (IS), computer science, and cognitive psychology. Information is created, stored, retrieved, distributed and analyzed by processes that manipulate tokens. The second view is information as syntax, based on Shannon's mathematical theory of information. Information is the measureable relationship among tokens that reduces entropy. The tokens, the letters in a sentence, or the symbols in an equation, or the messages in a communication have syntax, a relationship with one another. When defined as representation, information is meaning. Meaning emerges from a sign that stands for an object to a particular observer. As adaptation, information is perceived by a system (e.g. a person, an organization) to adapt and survive.

The Adaptation View

The adaptation view requires an ontological shift, from the belief that there is an objective reality independent of perception, to the recognition that reality is subject to perception. Information in the adaptation view starts with perception; perceptions that lead to change (McKinney and Yoos, 2010). Information in this sense is semantic and meaningful as it creates a change.

For example, if a driver perceives that she is speeding and this perceived difference makes the driver adapt, and change to a different, slower speed then she was informed. Being informed is perception based and dynamic; all information in the adaptation view is perceived by the individual. That is, the environment, that which is external to the perceiver, does not externally provide information. Thus, information in the adaptation view depends completely on the individual's perception and what, if anything, the individual does about his/her perception. In the example of the driver, if the driver noticed she was speeding but did nothing about it, there was no information.

A number of subjectivist theories of adaption use information to describe how systems adapt to perceptions (Brier, 2005; Checkland, 1987; Miller, 1978). However, very few of these theories offer a specific concept of information. To better understand the adaptation view a subset of these theories that include an information concept—autopoiesis and cybernetics are considered next.

Autopoiesis literally means "auto (self)-creation" (Maturana and Verela, 1980). The term describes the nature of living systems. Autopoietic systems are a network of processes that produce the components that continuously regenerate the network of processes that produced them (Maturana and Varela, 1980). Autopoietic systems include beehives, human beings and societies. Autopoiesis explains system adaptation as regeneration, or perpetual self re-creation. Information for an autopoietic system is not externally imposed by the environment of the system or how the system perceives the world, and not what the system knows about itself, but rather how the system recreates and adapts itself based on what it perceives. "…the nervous system does not 'pick up information' from the environment, as we often hear... The popular metaphor of calling the brain an 'information-processing device' is not only ambiguous but patently wrong" (Maturana and Varela, 1987, p. 169).

Cybernetics is the study of self-regulating systems (Wiener, 1961). In a cybernetic system information is what is exchanged with the environment as a system changes and makes it change felt upon the environment. A change made by the system leads to a change in the system's environment. This change is then fedback to the system as information. The system again takes an action. Every cybernetic system strives to remain viable by regulating its changes within tolerance limits in the face of perturbations from the environment impinging on the system. For example, the thermostatic system in a building strives to keep room temperatures at a constant level by initiating heating or cooling, based on the sensed temperature. Moreover, every cybernetic system is contained by a super-system, controlling the subsystem by regulating the set of possible actions of the subsystem. In the example of the building thermostatic system, the second order cybernetic system is the human building occupant who regulates the reference room temperature, warmer when present for comfort, and cooler when absent for energy savings. This hierarchy of systems is evident in Checkland's self-referencing systems: "…we think about ourselves thinking about the world and we change" (Checkland and Howell, 1998, p. 99). Information in cybernetics is feedback to the system that precipitates change.

One strength of the adaptation view is it is consistent with the common elements of the term information: signs, perception, communication and change. The adaptation view uses data and symbols as synonyms, and as tokens that are communicated between systems.

We propose a theory of information consistent with this adaptation view. It affixes the term data to external tokens and information as an internal construct of perception that leads to change. Our theory of information places a well-known definition of information into the adaptation view, and relates how this definition with adaptation assumptions can be used to create a theory of information particularly well suited for the current business environment.

THE DIFFERENCE THEORY OF INFORMATION

The difference theory is built on Gregory Bateson's (1973) classic definition of information as "any difference that makes a difference." This definition of information forms the foundation of the difference theory. The difference theory of information is the set of the following two statements. Following these statements we first expand on the specific concepts in the statements, then give examples of the terms and implications of the theory using business and IS examples.

- **Environments propagate differences.**
- **Systems perceive differences based on criteria, and conceive information.**

When viewed as a difference that makes a difference, information is change; it is neither a thing nor a representation. The first difference is a perceived difference by the system. The second difference is a change in the system. The first difference, labeled elsewhere as an un-interpreted difference (Floridi, 2011) or a distinction (MacKay, 1969), is a perceived nonuniformity that leads to the second difference—a change, an adaptation by the system perceiving the nonuniformity. More specifically, information changes *the possibility of how the system will act*. In human systems this is a change of mind.

For information to be conceived a system must first perceive a difference. These differences are propagated, generated, by the environment around the system. Perception is the awareness, or apprehension of a difference. Systems perceive differences; these differences, these nonuniformities, are the only way systems are aware of their environments. Systems can perceive differences in objects (e.g. color, weight, texture, size) as well as concepts (simplistic, useful, costly, reliable). Objects are not assumed, only perceptions. If the environment propoge, there are no differences to perceive and so no information is possible for the system.

To perceive a difference the system must have a criterion. Criteria are the attributes on which nonuniformities are perceived, they are the dimensions of the first difference. These dimensions may be simple, such as color, velocity, or cost; or criteria may be a composite such as variable cost, inelastic demand, or deceptive velocity. Without a criterion a difference is never perceived. By learning new criteria, a system can perceive more differences. Criteria are learned through experience or education. This learning loop—learn criteria, use criteria to perceive, learn more criteria and so on—is critical to living system adaptation.

Differences are *per*ceived (noticed, observed, apprehended) by the system; information is *con*ceived (created, comprehended) by the system. In living systems, perception is done by the senses, conception by the mind. Conception and perception frequently occur simultaneously, but may not. For example, conception lags perception when a system reflects. Both perception and conception are acts of particular systems, and therefore information is unique to each system. Information depends completely on the observer-system; the environment does not externally impose information on the observer. Differences are not "out there" for all observers to perceive in common. Differences must be both perceived and conceived by each system to become information.

To begin applying this theory, consider symbolic analysts examining a sheet of numbers. What the analysts hold in their hand are symbols and data. When an analyst perceives differences and those differences change the analyst's mind, information is conceived. Data are always external to the analyst; information is a change of mind. The theory also implies that one system cannot directly inform another. An analyst can communicate data—symbols and tokens—to another analyst, but not information. A system can only output data that if perceived by another system may lead to information. What is exchanged with other systems is data; perception and conception of information cannot be exchanged.

An Analyst, End User and an Error Message Example

An IT analyst and an end user (two *systems*) are looking at an error message on the user's computer. The end-user's software has propagated an error message that is different from other errors the end-user has seen. Both the end user and the IT analyst are using criteria to perceive differences that can change their minds. Without a change in mind, they are stuck and cannot adapt to this screen.

> ERROR MESSAGE "To perform this action, first modify your permissions via the users' rights utility in the system control panel. See System Directive 126.093.1, Jan, 2012."

The two participants see the same screen. Perception is possible because this screen is *different* in several ways from the screen that produced it, the screen that was expected, and other error screens. What is perceived by the IT analyst and the end user are these differences. That is to say, neither participant can perceive elements that are the same—the unchanged lighting on the screen, the consistent smell in the room, the unchanged background color, and the static location of the pointer.

The IT analyst and end user are looking at the same screen but they perceive their own differences. They may share some criteria such as recent events on this machine, and preceding keystrokes that led to this screen (as explained by the user), the IT analyst *is* the IT analyst because he has learned unique and useful additional criteria from experience or education that allow him to perceive more differences in the environment. These criteria may include day of the week, incompatible programs, and current malware—dimensions useful in this setting that may make a difference. Because the analyst perceives more, there is a greater chance that one of these differences will change the analyst's mind. One example of information conceived by the analyst occurs when the analyst's mind has changed from diagnosing the problem to attempting solutions.

An End User New System Reaction Example

Here we apply the difference theory to the common but often under anticipated phenomenon of user resistance to a new IS. A common reaction by end users is that the new system is hard to use or is poorly designed. Here we assume users were well interviewed prior to implementation about system uses, and they have received adequate training. However, in their words, they are having difficulty finding their "information", and are reluctant to experiment with new features of the system.

According to the difference theory, users had become accustomed to informing themselves from the data in the previous IT system. Without being aware of it, they had learned how to perceive the data they needed, and conceive information from it. Informing had become automatic and effortless. As a result users believed their information was in the system or that the system directly delivered information to them, not realizing their own role in conceiving information. It is not surprising that users believe the system contains their information, as it is labeled an information system, not a data system.

When a new IT system is now presented to them users must make an effort to find and perceive differences in the data they need. Making this more difficult, the data may be in a different format, may be based on new measures, or may be spread out over several screens. These issues make perceiving data and conceiving information much more difficult than before. Given time and motivation, the new system will become as effortless to use as the previous system, but in the interim, users are always working harder to inform themselves. Users typically do not realize that the work is necessary and normal with all new systems and they often blame the system for hiding the information that was so obvious in the earlier system. Designers cannot provide users with what they want, what users think is possible—an information system—a system where differences are already conceived, into information. Absent the difference theory, users and designers struggle to understand each other, place blame accurately, or fix the development process for new IS.

The difference theory helps explain this initial reaction. Designers, who are invested in the project, have the natural motivation to learn where to find their data and how to conceive it in the new system. As a result, they are quite willing to work hard to create information from data. These efforts are rewarded; they see very positive benefits in the new system. Designers believe the new information system has their information, or equivalently, has all the right information. Because the system has the right information they believe this information will be easy for users to find and use. As a result they oversell the new IT system based on the information they can conceive.

Each end user has different criteria they use to create their information from an IS. In a sense, each IS creates a unique system when an end user conceives their own information from data. However, without this theory, end users and designers may believe there is only one system. This one system view is evident when the terms "as-is" or "to-be" are used. With this theory there are as many as-is and to-be systems as there are users. While data systems can be described with these labels, designers must keep in mind the goal of the data system is informed users and design accordingly.

Our theory helps the IT manager to also better understand why users relentlessly seek changes in systems during and after development. Traditional design theories suggest that this scope creep is due to poor analysis by designers. This view is based on the premise that if the development is done well, the right information is provided, the user will be satisfied, and no new changes will be requested. On the other hand our theory proposes that all users adapt, they change their mind, and seek new differences to continue to inform themselves with their new mind. Adaptation of the end user's mind is normal but it creates new demands for information. However all information systems put limits on the rate of information conception and adaptation by users. Information systems change more slowly than the criteria employed by end users. Users learn, and convert new differences into information by using new criteria. As a result, developers should recognize scope creep as a natural, positive aspect of working with adaptive users rather than a sign of poor design or difficult users. Designers should recognize that new IS must be able to change to respond to user needs to adapt. Adaptive information systems should be built to be changed the day they are delivered. Further, IT development life cycle models should add continual updates to the maintenance phase, and perhaps re-label it the adaptation phase.

CONCLUSION

We have proposed a new theory of information. Along the way we have also specified a definition of data as tokens or symbols that can be perceived as different. This distinction between data and information makes a difference to IT community—the former are typically processed and manipulated by machines, and the latter by people. Having defined the difference information theory, we applied it to two specific business contexts. While our primary concern is to demonstrate the usefulness of the theory for symbolic analysts and managers, the theory also applies to all systems.

Further research is needed to better relate the constructs of this theory with ongoing developments in the philosophy of information, and with concepts in emerging information domains such as situation semantics (Barwise and Perry, 1983; Cooper, Mukai and Perry, 1990), semiotics (Brier, 2005; Sebeok 2001), and information science (Bawden, 2007, Capurro and Hjorland, 2003). Further research may improve our understanding of how criteria are acquired, communicated, and learned and how criteria are used in group settings. In addition, the implications for business have only been sketched. More clear applications of the theory to other business contexts might identify important new insights or needed extensions of the theory.

Finally, we acknowledge something of a paradox in our theory: we have attempted to communicate information to you, the crux of which is that information can't be directly communicated. The resolution of this paradox lies in the recursive feature of the theory—the theory can be applied to itself. The theory begins as data—words on a page—that you perceived and conceived into information about information. The test of this hypothesis is whether your informing process has been improved. Use this theory and see if you change your mind about how you change your mind.

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